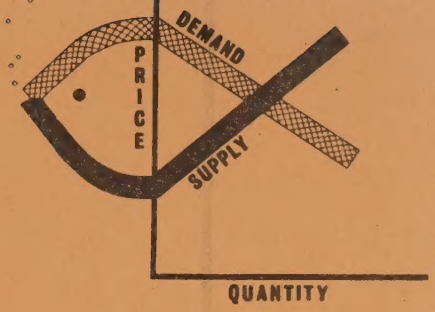

ESTIMATION OF THE ECONOMIC BENEFITS TO FISHERMEN, VESSELS AND SOCIETY FROM LIMITED ENTRY TO THE INSHORE U. S. NORTHERN LOBSTER FISHERY

BY

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Introduction

The inshore northern lobster fishery ranges from Labrador to Delaware (Figure 1) with catches being most abundant in the rocky coastal zone from the Gulf of St. Lawrence in Canada to Southern New England. The fishery is largely based upon fishing wooden traps or pots in inshore areas. U.S. landings of trap caught northern lobsters increased from approximately 23 million pounds in 1950 to a peak of over 29 million pounds by 1957. Since 1957, landings have fallen off reaching a low of but 22 million pounds in 1967. Despite the poor performance of production over the 1950-67 period, the number of lobster traps fished per year (i.e., a proxy for fishing effort) has

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* The author would like to express his appreciation to Richard Kinoshita for his splendid assistance in carrying out this research project. Ernest Carlson also contributed greatly to this effort through his work entitled, "Bio-Economic Model of a Fishery" Working Paper No. 12 (Division of Economic Research, Bureau of Commercial Fisheries). The views in this paper do not necessarily reflect the views of the Bureau of Commercial Fisheries.

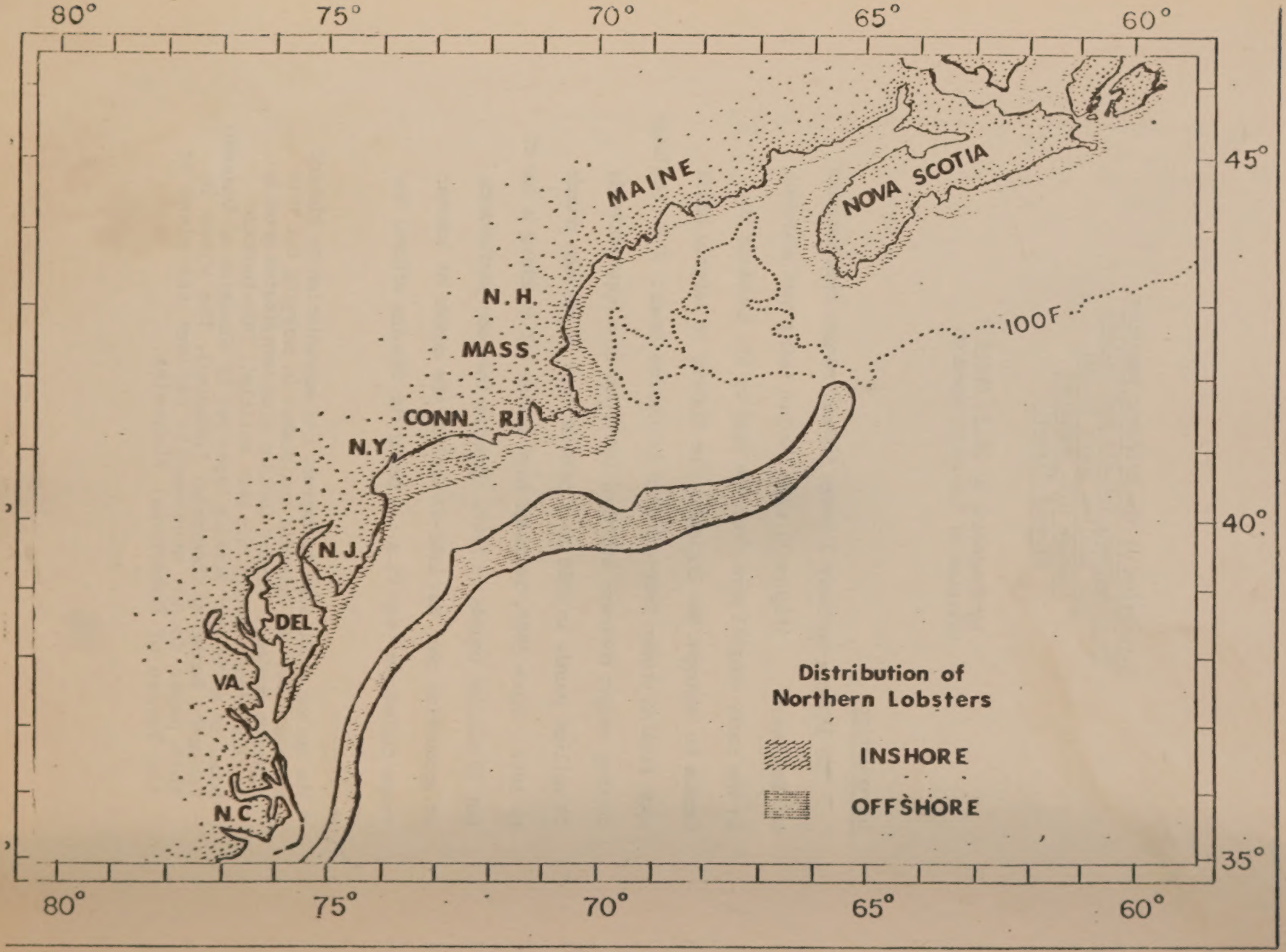

Figure 1
Distribution of Northern Lobsters

has increased secularly from approximately 579,000 in 1950 to over 947,000 in 1966.

The increase in fishing effort is accounted for by the rapidly increasing market for lobsters of all species. In sharp contrast to the poor growth in physical output of inshore northern lobsters, the value of the fishery has increased from approximately $8.3 million in 1950 to over 19.5 million in 1966. The growth in the value of the inshore northern lobster landings is attributable for the most part to a rise in the ex vessel price from 36 cents per pound in 1950 to over 76 cents a pound in 1966.

Unlike most industries, the inshore northern lobster industry is faced with a common property resource. The nature of this resource produces many unique problems and has given rise to many "conservation" objectives. Because unlimited entry to a common property resource produces excess capacity, it is the purpose of this paper to present a theoretical and empirical basis for the "conservation" of capital and labor in exploiting inshore northern lobster resources. We shall define "conservation" in a broad sense to include the efficient and economic use of capital, labor and the northern lobster resource. An attempt will be made with available data to calculate the economic benefits to fishermen, vessels and society from a policy of limited entry to the fishery. We shall also discuss the mechanics of limiting entry.

Inshore Northern Lobster Productivity Relation, 1950-66

To discuss the basic determinants of productivity in the U.S. inshore northern lobster fishery, we assumed the following production function:[1]

$$(1) \quad \frac{Q}{T} = v + bT + z°F$$

where,

Q = landings of U.S. northern lobsters by traps (i.e., inshore);

T = traps fished

°F = mean annual seawater temperature, Boothbay Harbor, Maine

If seawater temperature is held constant at some level, (1) becomes

$$(1a) \quad \frac{Q}{T} = a + bT$$

where,

$$a = [v + z°\bar{F}]$$

Although observations on inshore landings are available and fairly accurate, measures of effort are less precise. That is, we do not have a series on the number of "trap days fished. However, we do have observations on the total number of traps fished per year. Therefore, the traps fished represent a proxy for the aggregate amount of capital (and labor since there is approximately one man to each vessel) applied to harvesting the resource.

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[1]The sign of "b" is hypothesized to be negative while that of "z" should be positive.

Many have commented on the effect of effort and temperature on catch per unit of effort as specified in (1). Pontecarvo (1961) has inciated that changes in the northern lobster population since 1800 are consistent with the behavior of other populations subject to increasing fishing intensity. That is, systematic fishing has materially altered the composition of the lobster population and reduced the average size of the lobster caught from 5 pounds in 1800 to approximately 1 pound today. Dow, Harriman, Pontecorvo and Storer (1961) indicate that the decline in the unit size of the lobster over the years is evidence that the resource is being fished out. Pontecarvo (1961) further states, "The fishery [northern lobsters], in fact, is haunted by the spectre of overfishing, which appears possible because of the easy accessibility of most of the inshore population."

Unquesticnably, Dow has been the most prodigious writer on the Maine lobster fishery which is a large percentage of the total inshore northern lobster fishery. Dow has argued that economic variables such as effort and the environmental variables temperature have been largely responsible for fluctuations in the catch of lobsters (1967). After a recent review of the literature, a Bureau of Commercial Fisheries study group (1969) concluded that, "It should be noted here that the decrease in U. S. coastal catches and catch per effort over the past ten years is believed to be partly, if not largely, associated with a long-term trend of declining water temperatures which began in the mid-fifties; there is now evidence that the trend is reversing and mean temperature appears to be

returning to more optimal levels."[2] The "least-squares estimates" of the parameters of (1) using data over the 1950-66 period are the following:

$$(2)\quad \frac{Q}{T} = -48.3992 - \underset{(-3.37)}{.000024T} + \underset{(3.58)}{2.13°F}$$

$$R^2 = .96 \qquad D - W = 2.05$$

Both T and °F are statistically signigicant at the 5 percent level and exhibit the correct sign. An increase of one-hundred thousand traps fished will depress landings per trap fished by 2.4 pounds. An increase of one degree (F) increases yield per trap by 2.13 pounds. Using the average yield per trap over the 1950-66 period, a one degree (F) increase in temperature would increase productivity (Q/L) by about 5 percent holding the level of effort constant. Dow (1966, p. 29) states that "there is evidence that sea water temperature fluctuations influence annual landings about 5 percent per one degree (F) of change." Figure 2 shows the predictive accuracy of (2). If we insert the 1966 level of temperature (°F = 46.0) in (2), we obtain a new yield function holding temperature constant.

$$(2a)\quad \frac{Q}{T} = 49.44 - .000024T$$

Let us now multiply (2a) by T to obtain the total yield function:

$$(3)\quad Q = 49.44T - .000024T^2$$

Since this a a parabolic yield function, it has a unique maximum. For (3), the Q_{max} = 25.459 million pounds with a

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[2]McLeese (1956) and Wilder have also demonstrated the high sensitivity of lobsters to change in seawater temperatures.

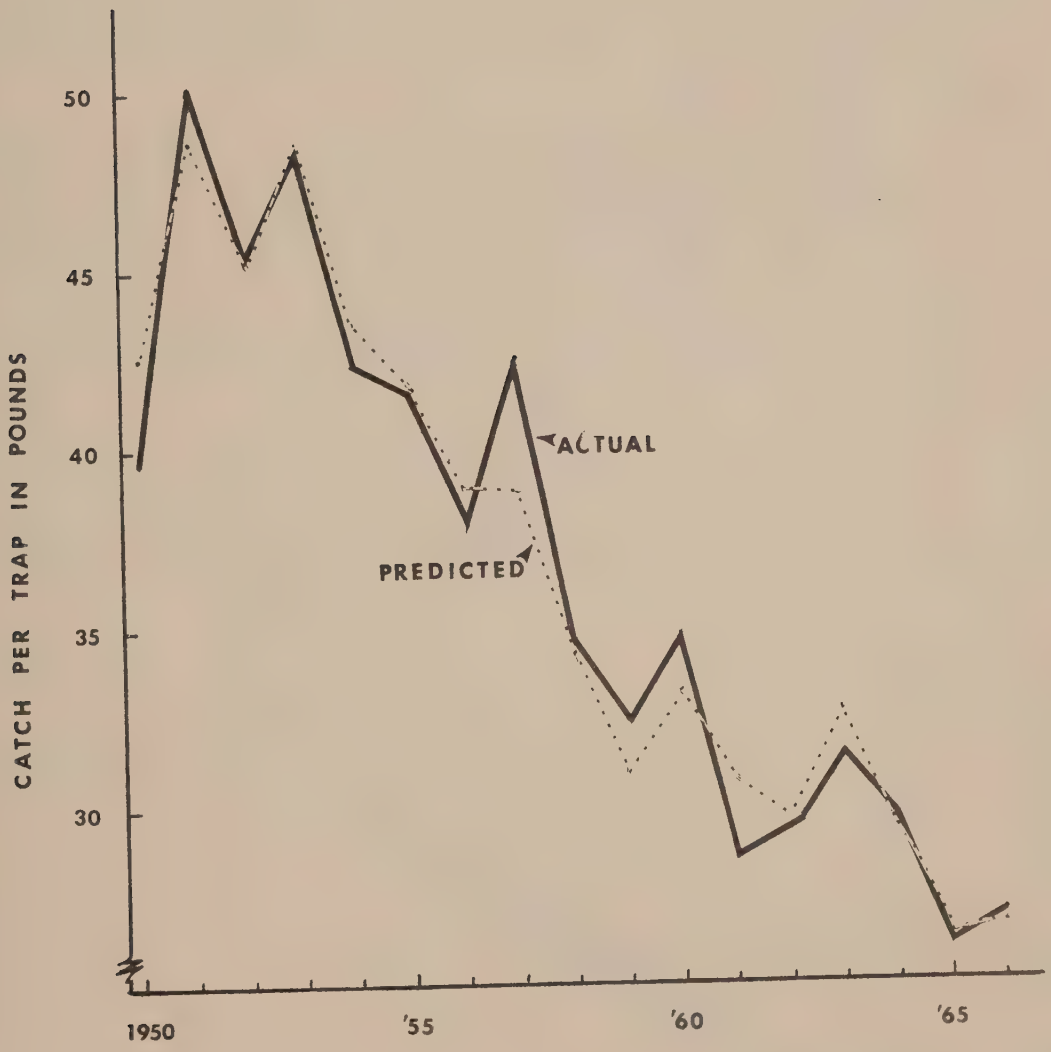

Figure 2.--Actual and predicted catch per trap for U.S. inshore northern lobsters, 1950-66.

T_{max} = 1,029,962 traps fished per year at a water temperature of °F = 48.0. Figure 3 shows the effect of water temperature on the yield function for trap caught northern lobsters. The 1966 level of effort or 947,113 traps fished is just under that level estimated to take the maximum sustainable yield from the fishery.

On the basis of equation (2), it would appear that about 50 percent of the decline in catch per unit of effort since 1950-52 is due to a decline in water temperature with the balance of the decline due to increases in fishing effort. This is shown below:

	$\frac{Q}{T}$ (pounds)	Temperature (°F)
1950-52 (Average)	45.0	50.3
1964-66 (Average)	27.6	46.2
Difference	-17.4	-4.1(2.126889)* = -8.7

% of decline in Q/T due to °F = $\frac{-8.72}{-17.4}$ = 49.88%

* parameter of °F in (2)

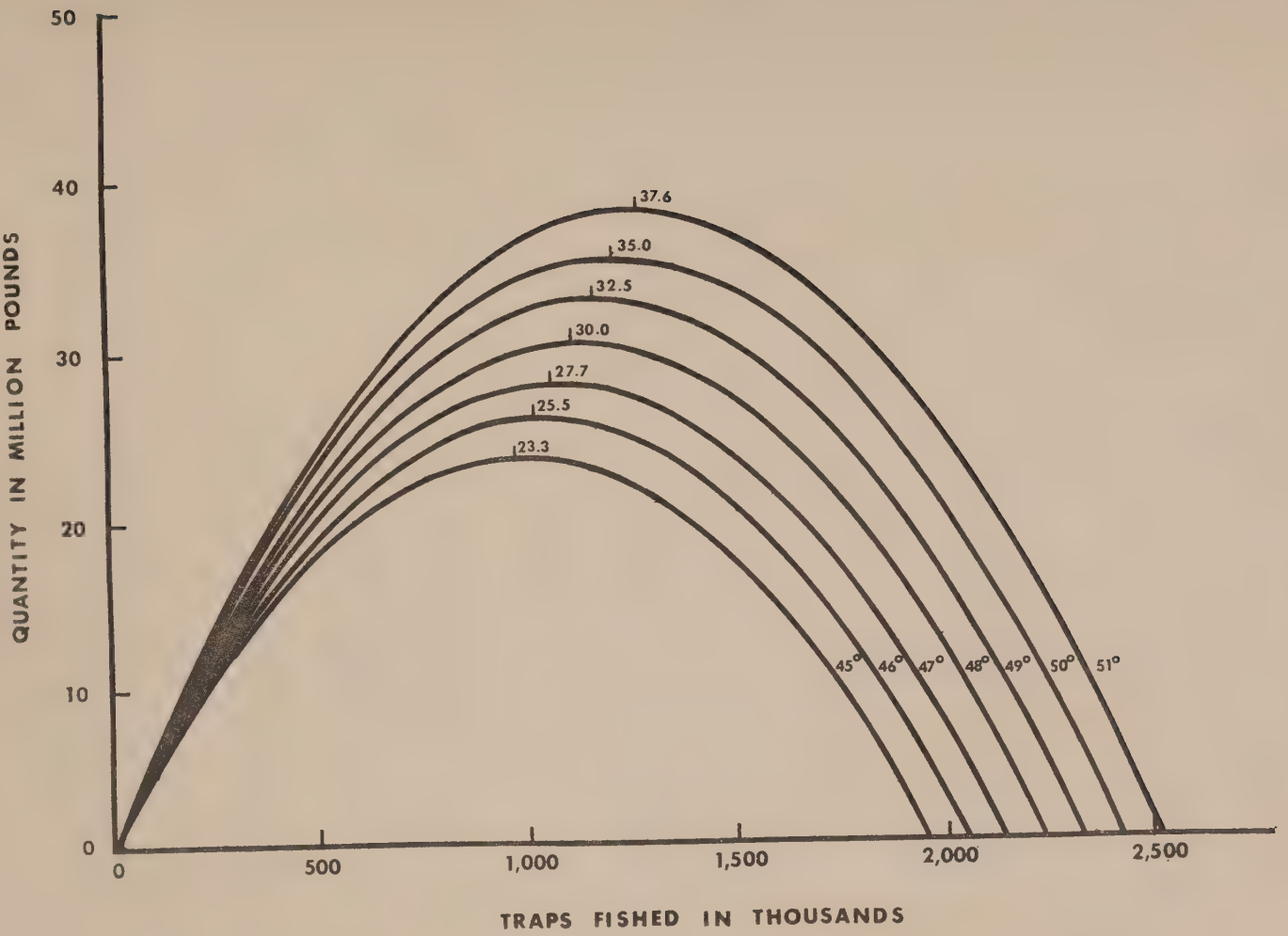

Figure 3: Relation of U.S. Inshore Northern Lobster Landings to Fishing Effort and Seawater Temperature, 1950-66.

With the above relationship established, let us now consider the cost of effort applied to the fishery.

Cost and Earnings of Lobster Boats, 1966

Limited data are available on cost and earnings of lobster boats. For the purpose of this analysis, data were obtained from BCF's Division of Financial Assistance on inshore lobster boats. The data indicate that the total cost of running an inshore lobster boat is composed of (1) operating expenses; (2) fixed expenses and (3) opportunity cost of fisherman and boat. Put differently, total cost per boat (TC_B) may be broken down into the following components.

Total Cost (TC_B) = Operating Expenses

Bait (B)
Fuel (F)
Repairs (R)

Fixed Expenses
Depreciation (D)
Interest (I)

Opportunity Cost of Fisherman and Boat Labor (L) Capital (C)

Each component of cost can be expressed as a function of the "effort" expended by the individual boat. That is, these costs, in the main, will be incurred even if the vessel catches no lobsters during the year. Hence, the cost of effort is independent of the volume of landings. Based upon an analysis of the data, the following relations were derived for a full-time inshore lobster fisherman:

(4) $B = \$2.25\ T_B$

Equation (4) states that annual bait cost is a function of the number of traps fished per boat, T_B. A full-time fisherman usually fishes approximately 563 traps. For 1966, it cost approximately $2.25 per trap yearly for bait.

(5) $F = \$.37\ G$

Equation (5) states that fuel costs depends on the number of gallons of gas used up by making approximately 146 trips per year. $.37 per gallon was charged in 1966.

(6) $R = \$3,000.00$

It is assumed that repair and maintenance for 1966 will average $3,000.00.

(7) $D = D_H + D_E + D_O$

Equation (7) indicates that aggregate depreciation is divided on hull (H); engine (E) and other equipment (O). These components may be espressed as follows:

(8) $D_H = .10\ H$

(9) $D_E = .20\ E$

(10) $D_O = .10\ O$

In equations (8) - (10), H, E and O are the market value of hull, engine and other equipment respectively. The depreciation rates are those used in common industry practices.

(11) $I = .06M$

Equation (11) indicates that interest cost depends on the amound of indebtedness, M. Six percent was a normal borrowing rate in 1966.

(12) $L = 5,202.48F$

Equation (12) indicates that labor cost is a function of the competitive wage rate (i.e., opportunity cost of lobster fisherman) multiplied by the number of fishermen employed on the boat.

(13) $C = .15NW$

Lastly, equation (13) states that capital cost depends on the competitive rate of return on capital multiplied by the equity of the boat owner. Because of the riskiness of the lobster fishery, the competitive rate of return was set at 15 percent.

For 1966, we have determined the relevant variables listed above for a full-time equivalent northern lobster boat:

$T_B = 562.8$ traps

$G = 1884$ gallons

$D_H = \$2,320.00$

$D_E = \$844.00$

$D_O = \$4,902.00$

M = 4,820.00

F = 1

NW = $4,820.00

Substituting the above values in equations (4) - (13), we have the following $\overset{\wedge}{\text{expense}}$ statement for a full-time lobster boat:

Operating Expenses		$4,965.16
Bait	1,267.28	
Fuel	697.88	
Repair	3,000.00	
Fixed Expenses		$1,180.20
Depreciation	891.00	
Interest	289.20	
Returns to Capital and Labor		$5,925.48
Labor	5,202.48	
Capital	723.00	
Total Expenses (TC_B)		$12,070.84

The basic reason for this exercise is to express the cost of effort (i.e., operating a vessel in the inshore lobster fishery) as a function of input prices. On the cost side, we may express the following prices as being exogenous to the lobster fishery:

1. Bait ($2.25)
2. Gas ($.37)
3. Repair ($3,000.00)
4. Depreciation rates (10%, 15%, 10%)
5. Market value of engine ($844.00)
6. Market value of hull ($2,320.00)
7. Market value of other equipment ($4,902.00)

8. Interest rate on debt (6%)
9. Annual wage rate ($5,202.48)
10. Annual return on capital (15 percent)

In other words, the average lobster vessel has no control over the above prices since they are determined in a competitive market. Increases in any of these prices will raise the cost of fishing effort. The other variables are technological variables such as gallons of gasoline or fisherman per vessel.

The Average and Marginal Cost of Landing Inshore Northern Lobsters, 1966

For the industry as a whole, the average cost of landing inshore northern lobsters may be expressed as the following:

$$(14)\quad AC = \frac{TC}{Q}$$

TC is total industry cost while Q is total industry output. TC is the product of the number of equivalent full-time boats (K) multiplied by the cost per boat, (TC_B) or

$$(15)\quad TC = K(TC_B)$$

For 1966, the number of traps per vessel is a constant or

$$(16)\quad \frac{T}{K} = c;\quad T = cK$$

Substituting (16) into (1a) and solving for Q, we have the following:

$$(17)\quad Q = acK + bc^2K^2$$

We may now substitute (15) and (17) into (14):

$$(18)\quad AC = \frac{K(TC_B)}{acK + bc^2K^2}$$

K may be factored out of (18) leaving,

$$(19)\quad AC = \frac{TC_B}{ac + bc^2K}$$

Now, we may solve the total yield function in terms of T or

$$(20)\quad T = \frac{-a \pm \sqrt{a^2 + 4bQ}}{2b}$$

Substituting (16) for T in (20) we have:

$$(21)\quad cK = \frac{-a \pm \sqrt{a^2 + 4bQ}}{2b}$$

or

$$(22)\quad K = \frac{-a \pm \sqrt{a^2 + 4bQ}}{2bc}$$

Substituting (22) into (19) and solving, we have the following average cost function for landing inshore northern lobsters:

$$(23)\quad AC = \frac{TC_B}{c\left[\frac{a \pm \sqrt{a^2 + 4bQ}}{2}\right]}$$

Hence, the average cost depends on the level of industry output assuming that the cost of a unit of effort (i.e., boat cost) remains constant. The AC rises with increased landings since higher levels of effortput additional pressure on the resource.

Most of the parameters of equation (23) have been estimated above. For 1966, the ratio of traps fished to full-time equivalent boats was 562.8. The number of lobster boats actually reported for 1966 was 6802. The boats represent a large number of part-time fishermen. Therefore, we converted the entire fleet to full-time equivalent boats. Remembering

that we developed cost and earnings data on a typical full-time lobster boat above, we merely divided total industry revenue by the average revenue per full-time boat. Therefore, we estimate that there are approximately 1,683 full-time equivalent boats operating in the inshore northern lobster fleet in 1966. This can easily be converted back to the actual fleet by computing the ratio of full-time equivalents to actual fleet. Inserting the estimated parameters into equation (23) we have,[3]

$$(24)\quad AC = \frac{\$12{,}070.84}{562.8\left[-49.44 \pm \sqrt{(49.44)^2 + 4(-.000024)Q}\right]}{2}$$

The total cost function for the inshore lobster fishery can be obtained by substituting (22) into (15) or

$$(25)\quad TC = TC_B\left[\frac{-a + \sqrt{a^2 + 4bQ}}{2bc}\right]$$

Equation (25) may be differentiated with respect to output to obtain the marginal cost function (MC) or

$$(26)\quad \frac{\partial TC}{\partial Q} = MC = \frac{TC_B}{c\sqrt{a^2 + 4bQ}}$$

Substituting the parameters into equation (26) we have,

$$(27)\quad MC = \frac{\$12{,}070.84}{562.8\sqrt{(49.44)^2 + 4(-.000024)Q}}$$

Table 1 shows the calculated average and marginal cost per pound of inshore northern lobsters for various levels of production.

---

[3] a = 49.44
b = -.000024

Table 1

Relation of
Average and Marginal Cost Per Pound of Inshore
Northern Lobsters to Landings and Effort, 1966

Landings (Mill. lbs.)	Effort (Thous. traps)	Average Cost Per Pound (Dollars)	Marginal Cost Per Pound (Dollars)
1.0	20	.438	.443
5.0	107	.458	.484
10.0	227	.488	.557
15.0	370	.529	.677
20.0	553	.593	.937
25.0	892	.765	3.228
25.459*	1,030	.872	∞
25.0	1,168	1.002	negative
20.0	1,507	1.616	negative
15.0	1,690	2.417	negative
10.0	1,833	3.930	negative
5.0	1,953	8.379	negative
1.0	2,039	43.743	negative

*Maximum sustainable yield

Source: Division of Economic Research

The Demand for Lobsters, 1947-68

Let us specify the following demand function for all lobsters:[4]

$$(28)\quad \frac{C}{N} = d + e\left(\frac{P}{CPI}\right) + g\left(\frac{Y}{N}\right)$$

where:

C = Consumption of all lobsters (northern, spiny, etc.)

$C = I + Q_o + Q_{IN}$

I = Imported lobsters

Q_o = U. S. production of lobsters (except inshore northern)

Q_{IN} = U. S. production of inshore northern lobsters

P = Ex Vessel price of northern lobsters

Y = Aggregate U. S. personal income (1957-59 prices)

N = U. S. population

CPI = Consumer price index

Equation (28) may be solved in terms of p or

$$(29)\quad p = \left[\frac{d}{e} + \frac{1}{eN}\left(Q_{IN} + Q_o + I - gY\right)\right] CPI$$

If Q_o, I, Y, CPI and N are held constant, equation (29) gives a unique relationship between the ex vessel price of northern lobsters and quantity landed.

Using data over the 1947-68 period, the parameters of equation (28) were estimated using least-squares:

$$(28)\quad \frac{C}{N} = -.2098 - \underset{(5.20)}{.01012}\left(\frac{P}{CPI}\right) + \underset{(11.35)}{.00078}\left(\frac{Y}{N}\right)$$

The numbers in parentheses are t-values.

[4]The sign of "e" if hypothesized to be negative.

R^2 = .913	D.W. = .733
Price Elasticity at Means = -.676	Income Elasticity at Means = 1.950

The predictive accuracy of equation (28) is shown in Figure 4. The fit seems to conform well to a priori theory. Per capita consumption of all lobsters has increased from .46 pounds in 1947 to .96 pounds in 1968. Although lobster prices have increases more rapidly than the general price level over the 1947-68 period and thereby tending to dampen per capita consumption of lobsters, the strong response of lobster consumption to increases in real per capita incomes more than offset the rise in prices.

We may derive the demand curve for inshore northern lobsters for 1966 by specifying the value of exogenous variables and inserting in equation (29)

N = 195,900 (thousands)

Y = $449,591 (millions)

CPI = 1.131 (1957-59 = 100)

$(Q_o + I)$ = 145,386 (millions of pounds)

The parameters, "d", "e" and "g" were estimated in equation (28). The final demand function for 1966 is the following:

(29) $P = 93.93 - .5705Q_{IN}$

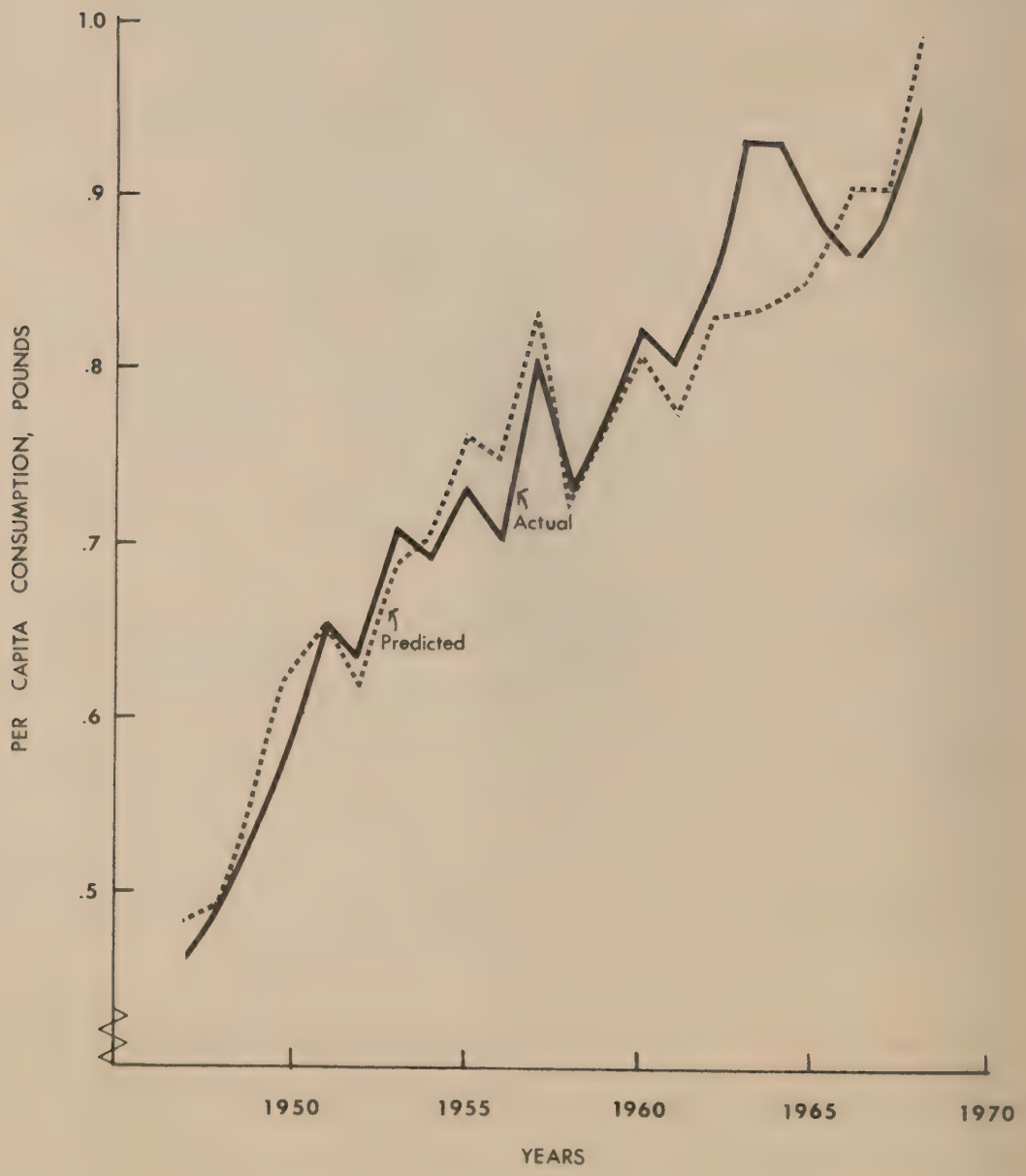

Figure 4 -- Actual and predicted U.S. per capita cons nption of all lobsters, 1947 – 68

Market Equilibrium, 1966

The demand and supply (average cost) functions for the year 1966 are shown in Figure 5. The supply function rises as the landings of inshore northern lobsters are increased to a point where the curve is tangent to maximum sustainable yield at 25.459 million pounds. Further fishing effort results in higher average cost per pound of lobsters landed and decreased production. The demand curve and average cost (supply function) intersect just below maximum sustainable yield. The predicted market equilibrium takes place at an ex vessel price of $.7952 and level of landings of 25.24 million pounds.[5] Apparently, the level of demand for northern lobsters has reached a point where it has enticed fishing effort just short of that required to maximize production.

In sum, the model seems to adequately describe the level of production, resource productivity, demand and final market equilibrium for the U.S. inshore

[5]The model cannot perfectly predict the observed market equilibrium since both the biological yield and demand functions are subject to a random error term. The actual ex vessel market price for 1966 was $.762 at a level of landings of 25.6 million pounds.

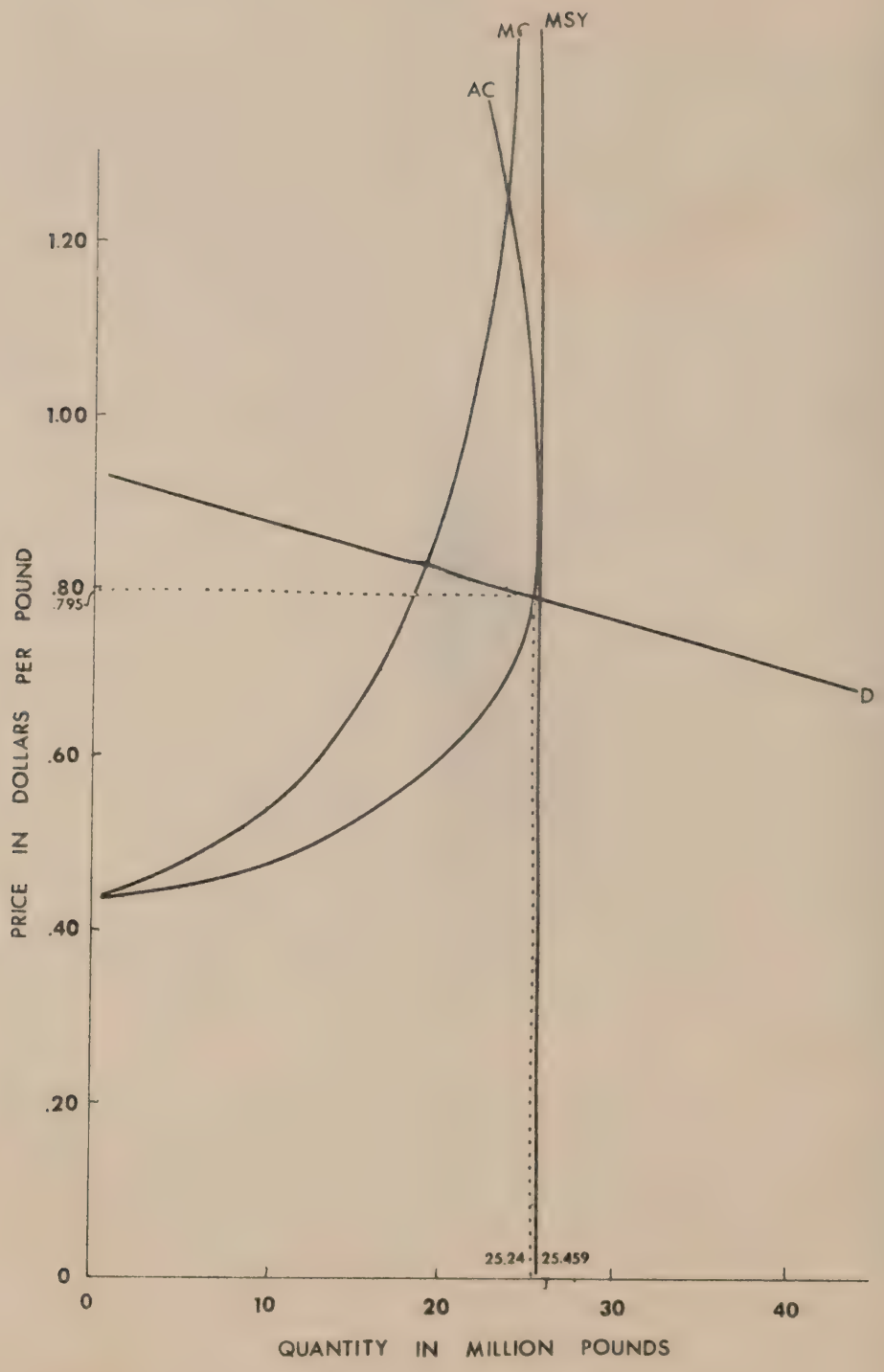

Figure 5--Market Equilibrium For Inshore Northern Lobster, 1966

northern lobster fishery. Hopefully, we have a model which links the most important exogenous variables such as input prices, population income and water temperature to such strategic endogenous variables such as price, landings and fishing effort. Hence, two classifications of variables may be established with respect to economic activity of the inshore lobster fishery.

Endogenous Variables	Exogenous Variables
(1) Landings	(1) Price of bait
(2) Traps fished	(2) Price of fuel
(3) Number of boats	(3) Repair costs
(4) Number of fishermen	(4) Depreciation rates
(5) Ex vessel prices	(5) Interest rates
	(6) Competitive return to capital and labor
	(7) Cost of boat and engine
	(8) Landings and imports of lobsters other than inshore northern
	(9) Aggregate U.S. personal income
	(10) U. S. population
	(11) Consumer price index
	(12) Mean annual water temperature

From the above list, it is quite apparent that the economic

changes in the inshore northern lobster fishery are influenced by at least twelve important variables which are determined outside the fishery (i.e., are given to the fishery). The model we have developed will enable one to access the individual impact of each of the twelve exogenous variables listed above.[6] For example, we are now capable of answering such questions as the probable impact of increased imports, rising boat costs, changes in consumer income and water temperature on landings, ex vessel prices and effort. This gives us a powerful tool in attempting to formulate a fishery management strategy.

The Economic Results of Free Entry to the Inshore Lobster Fishery : Present and Future

As shown in Figure 4, per capita consumption of all lobsters has nearly doubled over the 1947-68 period. This rising per capita consumption coupled with expansion in the U. S. population have created an ever increasing market for lobsters. The pressure of demand on the fishery resource has expanded effort in both U. S. and foreign lobster fisheries. Because entry to the fishery is not limited, effort (i.e., traps fished) has expanded to a point where maximum sustainable yield is amost attained.

[6] It should be pointed out that the natural environment in addition to water temperature may have a strong impact upon the fishery. We are not for a minute discounting the importance of nature factors. However, we have no way of systematically incorporating them into the model except as a random error variable in the yield function.

This is, of course, qualified by the level of water temperature. The MSY and effort associated with MSY will vary with changes in water temperature (see Figure 3).

To get some idea of the impact of future changes in demand on the inshore northern lobster fishery, we projected the demand to 1975. The following variables were projected to 1975:

N = 219.4 million (Bureau of Census)

Y = $660,098 (millions) (National Planning Association)

CPI = 135.3 (1957 - 59 = 100)

Q_o = 27.126 million pounds

I = 186.520 million pounds

} Based on Trend Over 1960-68.

The new demand function for 1975 becomes,

(30) $P = 155.51 - .60936\ Q_{IN}$

The expected increase in demand by 1975 will produce overfishing of the resource. The price will be $1.424 with a quantity landed of 21.555 million pounds. Of great significance, the quantity landed will be produced by 1,432,000 traps (Figure 6). According to the yield curve, this same production could be achieved with 628,000 traps. In essence, free access to the resource will create 804,000 redundant traps by 1975. This constitutes a tremendous waste of capital and labor. Unless a rational management scheme is instituted, we see every indication that free access to the resource will produce overfishing and a considerable waste of resources even before 1975. The above analysis, of course, assumes the 1966 water temperature. An increase in water temperature will mitigate

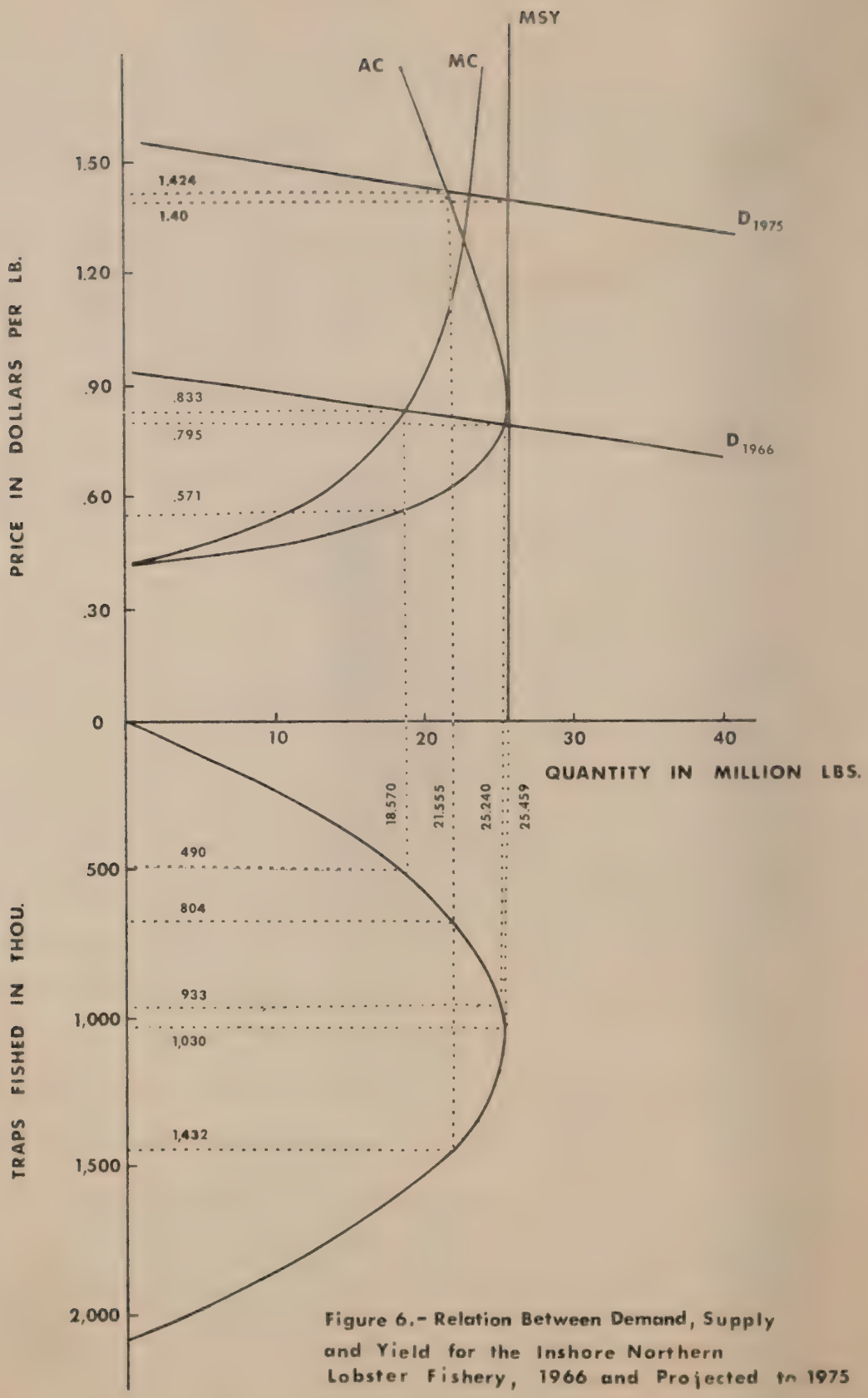

Figure 6.- Relation Between Demand, Supply and Yield for the Inshore Northern Lobster Fishery, 1966 and Projected to 1975

somewhat these disastrous projections.

The Optimal Management Strategy: A Critical Need

As indicated in the introduction to this paper, we desire a management strategy which will not only conserve the renewable fishery resource, but also conserve the use of other scarce factors such as capital and labor. Figure 6 shows the marginal cost of employing additional capital and labor in exploiting the resource. The marginal cost rises as output expands and is asymptotic to maximum sustainable yield. Beyond maximum sustainable yield, marginal cost is negative. We are only interested in marginal cost when it is positive. This indicates that both from an economic and biological point of view, we should never permit the level of effort to exceed that level necessary to maximize production.

The optimal management strategy for any fishery is to permit effort to expand to the point where the marginal cost of the resources (capital and labor) needed to produce a pound of fish is equal to the price consumers are willing to pay for that last pound of fish. The strategy of marginal cost pricing will insure that (1) economic efficiency will be achieved and (2) resource will not be exploited beyond maximum sustainable yield. For the inshore northern lobster fishery (in 1966), marginal cost is equal to price of $.8334 and a production of 18.57 million

million pounds for 1966.[7] According to the calculations, the level of effort needed to achieve this optimum would be approximately 430,000 traps.

Maximizing Production vs Marginal Cost Pricing

One management strategy which has often been suggested is to control effort at the point of maximum sustainable yield from the fishery. Let us consider why this may be a sub-optimal strategy. For the inshore lobster fishery, if we allow effort to expand to maximize production, the marginal cost of the resources (capital and labor) used to exploit the fishery will exceed the average revenue from the fishery. Compared to the optimal position (marginal cost pricing), the maximization of production results in a net loss to society. The excess cost item represents the area above the demand curve but under the marginal cost curve between the production of 18.570 and 25.459 million pounds. When we maximize production, we are not conserving capital and labor; but wasting these resources since their marginal cost exceeds their dollar returns. This proposition implicitly assumes that these "wasted" resources could be allocated to other persuits in the economy where their returns would be equal to their marginal cost. In the short or intermediate period, this assumption may not hold.

7 It should be pointed out that this analysis is based upon the assumption that imports and other domestic production of lobsters remain constant in response to changes in market price because of the flatness of the demand function.

Table 2

Economic Consequences of Alternative Management Schemes for the Inshore Northern Lobster Fishery, 1966

Variables	Management Alternatives: Free Entry	Management Alternatives: Marginal Cost Pricing
Ex Vessel Price	$.7952	.8334
Landings (pounds)	25.24 million	18.57
Average Cost	$.7952	.5707
Effort (traps fished)	933,000	490,000
Full-time Boats (equivalent)	1658	871
Full-time Fishermen (equivalent)	1658	871
Returns to Capital and Labor Per Vessel	5923	$11,527
Loss to Society and/or Fishermen[1]	4,880,966 (Compared to MC=P)[2]	0

[1] Loss due to free entry and maximization of production is discussed in text.

[2] ($.8334 - $.5707)(18.57 Million Pounds)

Source: Division of Economic Research

It should be pointed out that the maximization of production and marginal cost pricing strategies discussed above practically coincide after demand for the fishery product reaches a certain level. That is, the marginal cost curve is asymtotic to maximum sustainable yield. This leads to an important point: At high levels of consumer demand, the maximization of production and marginal cost pricing for all practical purposes are identical strategies. The coincidence of these strategies at high levels of demand is an extremely important point to remember since it considerably reduces the complications of administering a management program.

This has special significance for the inshore northern lobster fishery. We have projected the level of demand to the year 1975. At this level of demand, marginal cost pricing and maximization of production come close to being an identical policy. Let us assume that the maximization of production is adopted as the management strategy. No more than 1,029,962 traps should be fished in any year. At the 1975 level of demand, 25.459 million pounds of lobster will be produced (MSY) at a price of $1.40 per pound. The average cost of production will be only $.87.24 assuming 1966 factor costs. This yields an average profit (rent) of $.52.76 per pound of lobster. If factor prices (i.e., bait, wages, maintenance etc.) increase by 2.0 percent per year to 1975, average production cost will rise by 18 percent over the 1966 level. Therefore, average cost of production will probably be $1.029 thereby yielding a profit per pound of $.371. Multiplying the profit per pound by the maximum sustainable

yield, we obtain economic rents of $9,445,289 which could be distributed to the following groups:

1)	Fishermen	$7,945,289
2)	Regulatory Authority for Management Investigations	500,000
3)	BCF for Research and Development of Gear and Biological Studies	400,000
4)	Fishermen's Loan Fund	50,000
5)	BCF Economic Studies	50,000
6)	State Agencies for Natural Resources* (Example: Sea and Shore Fishieries of Maine)	500,000
	TOTAL RENTS	$9,445,289

*should be pro rated among states on the basis of Lobster Landings

Therefore, all groups could share the economic rents. It would also place the fishery on a self-financing basis. This would relieve the Federal Government and States of the financial burden associated with the fishery resource.

Table 3 indicates the results of a limited entry program to maximize sustainable yield. The number of traps may be expanded by 96,962. This will also increase the number of vessels in the fishery. Despite the increase in the number of fisherman, annual income to labor and capital will increase to $10,265 (excluding an 18% increase due to general inflation which was included in the 1975 average cost projection) in the year 1975. Rents will, of course, get larger over time. The question of the distribution

Table 3

Economic Consequences of Limiting Entry so as to Maximize Sustainable Yield from the Inshore Northern Lobster Fishery: 1966 Compared to 1975

Economic Variables	Present Situation (Free Entry) 1966	Limited Entry at MSY (Annual Return) 1975
Ex Vessel Price	$.7952	$1.40
Landings (pounds)	25.24 million	25.459
Average Cost	$.7952	$1.029
Effort (traps fished)	933,000	1,029,962
Full-time Boats	1658	1830
Full-time Fishermen	1658	1830
Returns to Capital and Labor (per vessel)	$5,923	$10,265*

*[$5,923 + ($7,945,289) ÷ 1830]

Source: Division of Economic Research

of the increasing rents will have to be solved by government and industry together.

The Disposition of Rents and Administratively Controlling Entry

The principal thrust of this paper was restricted to a discussion of the economic results of limited entry. We have shown this above. Some have argued that the economic rent accruing to capital and labor shoud be taxed away. Reeves (1969) has proposed a hike in license fees to "eliminate" the marginal fishermen. He suggest that the present $10 yearly fee in Maine be raised $10 a year over the next nine years to a top of $100. In 1966, a little less than one half of the lobster fishermen were part-time. A part-time lobster fisherman is defined as one who gains less than one-half of his annual income from lobstering. The first step in most limited entry schemes is usually to restrict the fishery to full-time utilization of capital and labor. Reeves argues strongly for limiting the number of traps each fishermen is allowed to set. It is not quite clear whether both

of Reeves' proposals would result in the most efficient use of capital and labor unless accompanied by some system to encourage only the most efficient producers to the fishery.

Rutherford, Wilder and Frick (1967) in their study of the Canadian inshore lobster fishery endorse the system suggested by Sinclair (1960). They state,

> "An alternative management system is that suggested by Sinclair (1960) for the salmon fisheries of the Pacific Coast. This would use the licensing of fishermen to limit entry into the fishery. In the first stage, lasting about five years, licenses would be reissued at a fee but no new entries would be licensed, and it would be hoped that during the period there would take place a reduction in the labour and capital input, to take the maximum sustainable catch of salmon at a considerably lower cost. After the end of the first stage, licenses would be issued by the government under competitive bidding and only in sufficient numbers to approximate the most efficient scale of effort; the more competent fishermen would be able to offer the highest bids and it would be expected that the auction would recapture for the public purse a large portion of the rent from the fisheries that would otherwise accrue to the fishing enterprises under the more efficient production conditions in the fishery.
>
> An arbitrary reduction in the number of fishermen by restriction of licenses to a specified number would entail injustice and inequity as well as grave administrative problems in determining who should be allowed to continue fishing. The auctioning of licenses to exploit a public property resource is justifiable in a private enterprise system of production, particularly when the state is incurring heavy expense to administer and conserve the resource; the recovery by the state of some

> part of the net economic yield by means of a tax on fishermen (or on the catch) would recoup at least part of such public expenditures, or could be used to assist former fishermen, for instance, by buying their redundant equipment. A tax on fishermen through the auctioning of licenses has, at least, the merit of using economic means instead of arbitrary regulations to achieve a desired economic objective--the limitation of fishing effort to increase the net economic yield from the fishery. Regulations have to be enforced, usually at considerable cost, but economic sanctions tend to be, if not impartial, at least impersonal and automatic in their operation."

Conclusions

The purpose of this paper is to develop a framework by which we can look at the possible economic consequences of limiting entry to the inshore northern lobster resource. For this purpose the data are less than optimal. However, this does not mean that we cannot take steps in the direction of fishery management. In fact, these steps must be taken to protect the resource from destruction and achieve an economic optimum. It is hoped that the following conclusions will provide a helpful framework in which to consider the merits of limited entry:

1. For the inshore northern lobster resource, we see every indication that the fishery has achieved maximum sustainable yield. This has been brought about by a rapid expansion in effort (i.e., traps fished) produced by (1) free access to the resource and (2) a rising market for lobsters of all species; and (3) a secular decline in seawater temperature.

2. The market for lobsters of all varieties has expanded rapidly due principally to a high income elasticity. As indicated in 1, the expansion in the markets has been the principal reason for the heavy demands placed upon the resource. A continuance of this market trend coupled with unlimited access to the northern lobster fishery will ultimately destroy or seriously impair the viability of the resource;

3. To achieve economic efficiency, fishing effort applied to the northern lobster fishery should be much less than the level achieved in 1966 if marginal cost is to equal price.

4. We demonstrated that a management strategy of maximizing production through limited entry would be almost equivalent to marginal cost pricing by 1975. The rents derived from this strategy could make the fishery self-financing and raise fishermen's income from $5,923 in 1966 to $10,265 in 1975.

5. Much thought should be given to the short vs. long run changes which result from a system of limiting entry. Biological studies to assess the short run reaction of the lobster population to various rates of effort reduction should be instituted and blended into the analysis in this paper;

6. A change in the present regulations affecting the northern lobster fishery was not considered here. These regulations were taken as given to the economic and biological models. Further work will be done to consider how changes in existing regulations coupled with limited entry schemes will influence the economic outcome.

7. The reader should be aware that the above analysis does not consider inter-temporal maximization of welfare, (i.e., using discount procedures, etc.)

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APPENDIX

Table A-1

Various Economic Variables Associated with the Maine Northern Lobster Fishery, 1947-65

Year	Catch by Traps (Thou. lbs.)	Value of Catch by Traps (Thou. Dollars)	Boats	Fishermen on Boats	Traps Fished	Landings Per Trap (lbs)	Ex Vessel Price (cents per lb.)	Per Capita Consumption (All Lobster) (lbs.)	Ex Vessel Price Divided by Consumers Price Index	Per Capita Real Income (Dollars)	Mean Annual Seawater Temperature, Boothbay, Maine °F
1947								.4615	48.602	1515	
1948								.4815	49.630	1539	
1949								.5392	43.481	1523	
1950	20,914	8,284	6,858	7,224	578,930	39.6	36.2	.5848	42.947	1628	49.3
1951	24,752	9,328	6,300	6,608	512,812	50.2	36.2	.6507	39.944	1622	51.4
1952	24,681	10,470	6,695	7,130	544,730	45.3	42.4	.6383	45.610	1641	50.2
1953	27,510	10,688	6,563	7,413	569,081	48.3	38.9	.7100	41.491	1697	52.8
1954	26,628	10,250	7,437	7,740	628,209	42.4	38.5	.6905	40.779	1693	50.3
1955	27,887	11,004	7,534	7,781	669,229	41.7	39.5	.7342	41.832	1786	50.0
1956	29,387	11,583	7,573	7,917	666,887	38.1	45.6	.7038	47.423	1841	48.6
1957	29,356	11,263	7,457	7,777	688,815	42.6	38.4	.8062	38.959	1838	48.8
1958	26,243	12,900	7,574	8,117	753,503	34.7	49.3	.7356	48.213	1818	47.4
1959	27,752	14,042	8,148	8,426	856,794	32.4	50.6	.7634	49.024	1817	47.0
1960	30,346	14,658	8,188	8,668	844,110	34.8	46.5	.8298	44.345	1879	47.9
1961	25,601	13,662	8,165	8,472	895,098	28.6	53.3	.8096	49.942	1903	47.3
1962	26,726	13,769	7,374	7,713	909,318	29.4	51.5	.8549	48.083	1958	47.0
1963	25,210	15,298	6,756	7,518	866,900	31.4	56.2	.9382	51.921	2002	47.9
1964	30,129	17,672	7,028	7,871	904,233	29.7	65.9	.9346	59.343	2109	46.9
1965	34,711	19,799	7,321	7,980	949,045	26.1	75.9	.8838	66.050	2213	45.8
1966	29,418	19,512	6,914	7,560	947,113	27.0	76.2	.8727	66.657	2298	46.0
1967	27,198	18,907	-	-	-	-	85.2	.8821	71.977	2360	
1968	27,217	20,730	-	-	-	-	76.7	.9595	64.363	2420	

Source: Fishery Statistics of the United States; Survey of Current Business

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